ActivitySim: Large-scale Agent-based Activity Generation for Infrastructure Simulation

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The U.S. Department of Homeland Security aims to model, simulate, and analyze critical infrastructures and their interdependencies across multiple sectors such as electric power, telecommunications, water distribution, and transportation. Most infrastructure sectors rely on an underlying network that gets used by individual people and business entities, or alternatively speaking, there is a demand for the service that the network supplies. Demand on networks is largely generated by people as part of their daily activities, such as driving to work, using energy to cook or to heat the house, using water and sewage systems, or making phone calls. Thus, an accurate *model for the daily activities* of individuals is a prerequisite for a simulation of demand. An agent-based approach is the only modeling paradigm that allows us to generate demand shocks as an emergent property of the simulation. Demand can vary from a normal day to emergency scenarios. As an example, communication demand in emergency situations is different from a baseline demand due to individuals evacuating in large numbers leading to a geographic demand shift, and emotional turmoil leading to increased call volume. A model of dynamic demand that generates realistic data is an open research area.

ActivitySim is a scalable simulation tool that relies on a synthetic but statistically accurate population of the U.S. that was obtained using disaggregation methods applied to U.S. census data. ActivitySim is a part of a family of simulation applications that follow the SimCore modeling paradigm. SimCore is a library for building large-scale distributed-memory, discrete event simulations (DES) [1] using the open-source discrete event engine from the Parallel Real-time Immersive Modeling Environment (PRIME) [2] for passing events, event queue maintenance, and synchronization. It is composed of Entities, Services, and Infos. An Entity is an object or component in the system that we want to model. A Service represents the functionality or behavior of an Entity. An Info is an event exchanged between entities or services. ActivitySim's architecture includes the "reactive agent" extension to SimCore called AgentCore with additional Entity capabilities to perceive, think and act, and process patterns of behavior or production rules.

SimCore applications can be integrated with each other by exchanging events. Therefore ActivitySim, communication network simulators such as SessionSim and MIITS-NetSim, and/or a transportation simulator FastTrans can be run as a coupled model. For example, an agent can select his/her activity schedule in ActivitySim and travel between locations via FastTrans. Events are used for the initiation and completion of trips.

ActivitySim agents are *utility-driven* [3,4]—that is, each activity gives a certain amount of utility to an agent depending on how long the activity is being executed (see Fig. 1). Agents also have *priority functions* for activity types, where the priority of an activity intuitively increases usually with the time that has passed since the activity was last executed. Activity types have *constraints* that allow us to guide the timing of certain activities (such as that work should happen during the business hours). As optional modules, we (a) allow agents to have *personality types* (guided by standard models from social sciences), and

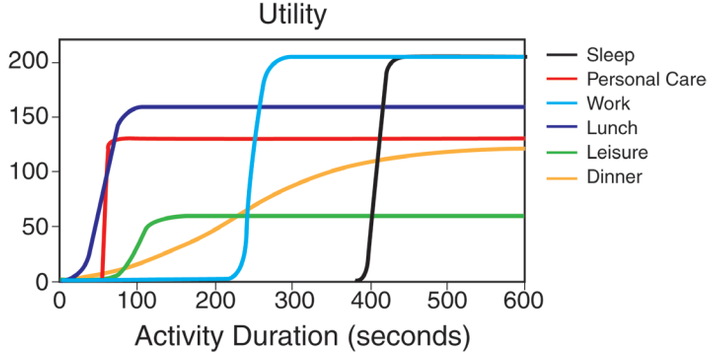

Fig. 1. Example Utility Functions.

(b) let agents guide their activity type selection by the *needs* that they want to satisfy.

The main loop of an agent consists of planning and replanning scheduled activities (see Fig. 2) and evaluation of the resulting updated schedule with respect to the agent's objective function. The objective function takes into account predicted utility as well as priority and constraints violations. The schedule optimization step can be performed through your favorite optimization method, such as the gradient method, local search, simulated annealing, or taboo search.

ActivitySim has been used to simulate the daily activities of a Twin Cities, MN synthetic population composed of 2.6 million individuals, with about 1M households and more that 480,000 different locations. The simulation was executed on the LANL Institutional Computing Coyote cluster and was run for 10 simulated days. Performance is shown in Fig. 3.

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[1] L. Kroc et al., LA-UR-07-0590 (2007).
[2] Parallel Real-time Immersive Modeling Environment (PRIME): http://lynx.cis.fiu.edu:8000/twiki/bin/view/Publuc/PRIMEProject
[3] J. Vhang-Hyeon et al., *GeoJournal* **53(4)**, 359-371 (2001).
[4] E. Galli et al., "ActivitySim: Large-scale Agent-based Activity Generation for Infrastructure Simulation," Agent-Directed Simulation Symposium, Spring Simulation Multiconference (2009).

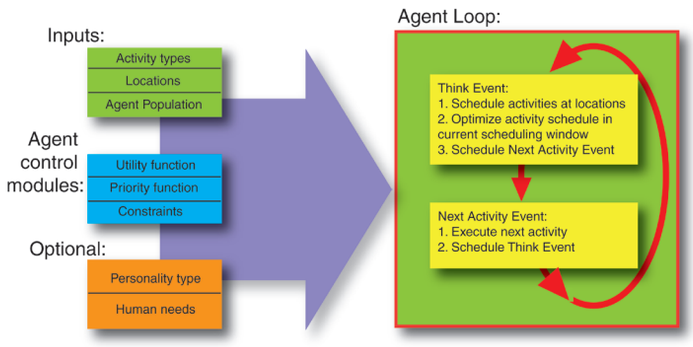

Fig. 2. ActivitySim Inputs, Modules, and Think Loop.

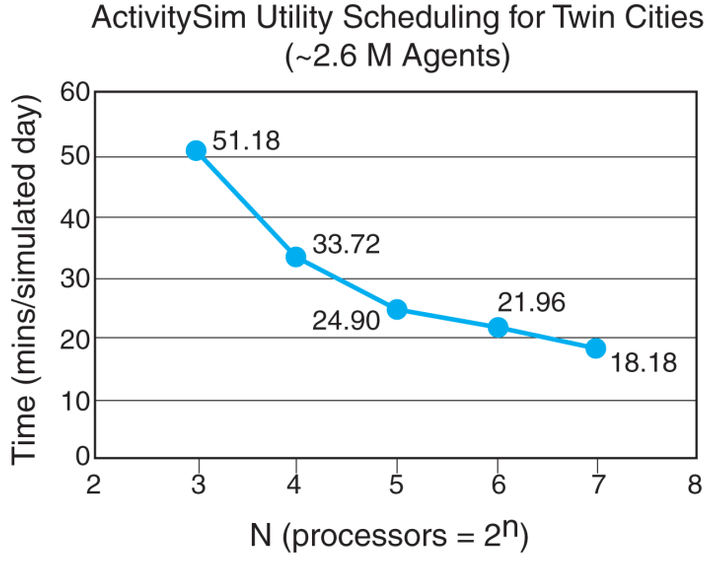

Fig. 3. The run time per simulated day.

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